WHAT IS CLAIMED IS:

1. A semiconductor device having a silicon surface of a predetermined crystal plane orientation, wherein:

the silicon surface has a prescribed arithmetical mean deviation of surface Ra that is not greater than 0.09nm.

2. A semiconductor device as claimed in claim 1, wherein the predetermined crystal plane orientation includes a substantial (100) crystal plane orientation.

3. A semiconductor device having a silicon surface with a substantial (110) crystal plane orientation, wherein:

the silicon surface has a prescribed arithmetical mean deviation of surface Ra that is not greater than 0.15nm.

4. A semiconductor device as claimed in claim 3, wherein:

the prescribed arithmetical mean deviation of surface of the silicon surface roughness Ra is not greater than 0.11 nm.

5. A semiconductor device as claimed in claim 3, wherein:

the prescribed arithmetical mean deviation of surface Ra is not greater than 0.09 nm.

6. A semiconductor device as claimed in claim 3, wherein:

the prescribed arithmetical mean deviation of surface Ra is not greater than 0.07 nm.

7. A semiconductor device as claimed in claim 3, wherein:

the prescribed arithmetical mean deviation of surface Ra is 0.02 nm or more.

8. A semiconductor device as claimed in claim 3, wherein the substantial (110) crystal plane orientation is selected from a group

consisting of (110), (551), (311), (221), (553), (335), (112), (113), (115), (117), (331), (221), (332), (111) and (320) crystal plane orientations.

9. A semiconductor device as claimed in claim 3, wherein the silicon surface has either (110) or (551) crystal plane orientation.

10. A semiconductor device comprising a field effect transistor having a source region, a drain region, a channel region, a gate insulation film on the channel region, and a gate electrode on the gate insulation film,

wherein:

the channel region is formed at a semiconductor silicon surface which has a predetermined crystal plane orientation;

the silicon surface having a prescribed arithmetical mean deviation of surface Ra that is not greater than 0.09nm.

11. A semiconductor device as claimed in claim 10, wherein the predetermined crystal plane orientation includes a substantial (100) crystal plane orientation.

12. A semiconductor device comprising a field effect transistor having a source region, a drain region, a channel region, a gate insulation film on the channel region, and a gate electrode on the gate insulation film,

wherein:

the channel region is formed at a semiconductor silicon surface which has a substantial (110) crystal plane orientation;

the silicon surface having a prescribed arithmetical mean deviation of surface Ra that is not greater than 0.15nm.

13. A semiconductor device as claimed in claim 12, wherein the prescribed arithmetical mean deviation of surface of the silicon surface roughness Ra is not greater than 0.11 nm.

14. A semiconductor device as claimed in claim 12, wherein:

the prescribed arithmetical mean deviation of surface Ra is not greater than 0.07 nm.

15. A semiconductor device as claimed in claim 12, wherein the substantial (110) crystal plane orientation is selected from a group consisting of (110), (551), (311), (221), (553), (335), (112), (113), (115), (117), (331), (221), (332), (111) and (320) crystal plane orientations.

16. A semiconductor device as claimed in claim 12, wherein the silicon surface has either (110) or (551) crystal plane orientation.

17. A semiconductor device as claimed in claim 12, wherein the gate insulation film comprises at least one selected from a group consisting of a silicon oxide film, a silicon nitride film and a silicon oxynitride film.

18. A semiconductor device as claimed in claim 12, wherein the gate insulation film contains therein a rare gas element.

19. A semiconductor device as claimed in claim 12, wherein the gate insulation film of the field effect transistor includes a dielectric film of a high relative dielectric constant.

20. A semiconductor device as claimed in claim 19, wherein the dielectric film includes at least one material selected from a group consisting of metal silicate, metal oxide and metal nitride.

21. A semiconductor device as claimed in claim 20, wherein the metal silicate consists of Si and at least one selected from a group consisting of Hf, Zr, Ta, Ti, La, Co, Y and Al.

22. A semiconductor device as claimed in claim 20, wherein the metal oxide consists of at least one selected from a group consisting of oxides of Si, Hf, Zr, Ta, Ti, Y, Nb, Na, Co, Al, Zn, Pb, Mg, Bi, La, Ce, Pr, Sm, Eu, Gd, Dy, Er, Sr and Ba.

23. A semiconductor device as claimed in claim 20, wherein the metal nitride consists of N and at least one selected from a group consisting of Si, Hf, Zr, Ta, Ti, Y, Nb, Na, Co, Al, Zn, Pb, Mg, Bi, La, Ce, Pr, Sm, Eu, Gd, Dy, Er, Sr and Ba.

24. A semiconductor device as claimed in claim 12, wherein the gate insulation film comprises a combination of films selected from a silicon oxide film, a silicon nitride film, a silicon oxynitride film and a dielectric film of a high specific dielectric constant.

25. A method of manufacturing a semiconductor device, comprising the steps of:

preparing a silicon semiconductor surface which has a predetermined crystal plane orientation; and

flattening the semiconductor surface to accomplish a prescribed arithmetical mean deviation of surface Ra which is not greater than 0.09nm.

26. A method of manufacturing a semiconductor device as claimed in claim 25, wherein the predetermined crystal plane orientation includes a substantial (100) crystal plane orientation.

27. A method of manufacturing a semiconductor device, comprising the steps of:

preparing a silicon semiconductor surface which has a substantial (110) crystal plane orientation ; and

flattening the silicon surface to accomplish a prescribed arithmetical mean deviation of surface Ra which is not greater than 0.15nm.

28. A method of manufacturing a semiconductor device, comprising the steps of:

preparing a silicon semiconductor surface which has a predetermined crystal plane orientation;

cleaning the silicon surface with an RCA SC-1 cleaning liquid with a reduced OH concentration and

forming an oxide film on the cleaned surface by oxidizing the cleaned silicon surface in an atmosphere containing oxygen radicals.

29. A method of manufacturing a semiconductor device, comprising the steps of:

preparing a silicon semiconductor surface which has a predetermined crystal plane orientation;

isotropically oxidizing the silicon surface to form a first oxide film on the silicon surface to flatten the silicon surface into the prescribed arithmetical mean deviation of surface Ra; and

removing the first oxide film.

30. A method as claimed in claim 29, wherein the isotropically oxidizing step and the removing step are repeated a plurality of times until the prescribed arithmetical mean deviation of surface Ra is achieved.

31. A method as claimed in claim 28, wherein said oxide film is used as a gate insulation layer or as a portion of a gate insulation layer, said method further comprising the step of:

forming a gate electrode on said gate insulation layer.

32. A method as claimed in claim 29, further comprising step of:

forming a gate insulation layer on the flattened silicon surface; and

forming a gate electrode on said gate insulation layer.

33. A method as claimed in claim 29, wherein the isotropically oxidizing step comprises the step of:

carrying out radical oxidation of the silicon surface at a temperature not higher than 550℃.

34. A method as claimed in claim 29, wherein the isotropically oxidizing step is carried out by contacting the silicon surface with ozone

water.

35. A method as claimed in claim 34, wherein the ozone water is ultra-pure water with 0.001ppm to 100ppm of ozone being dissolved therein.

36. A method as claimed in claim 35, wherein the ozone is included within a range between 1ppm and 30ppm in the ultra-pure water.

37. A method as claimed in claim 29, wherein the isotropically oxidizing step is carried out by contacting the silicon surface with hydrogen peroxide solution.

38. A method as claimed in claim 37, wherein the hydrogen peroxide solution includes, by weight, 30 to 100% of hydrogen peroxide.

39. A method as claimed in claim 34, wherein the isotropically oxidizing step is carried out for more than 10 seconds at a temperature between 10 and 30℃.

40. A method as claimed in claim 29, wherein the removing step is carried out by the use of a solution including hydrogen fluoride (HF).

41. A method as claimed in claim 40, wherein the solution is a mixed solution of HF and HCl.

42. A method as claimed in claim 40, wherein the solution includes HF and H_2O with dissolved oxygen of less than 100ppb.

43. A method as claimed in claim 27, wherein the substantial (110) crystal plane orientation includes (110), (551), (311), (221), (553), (335), (112), (113), (115), (117), (331), (221), (332), (111) and (320) crystal plane orientations.

44. A method as claimed in claim 29, wherein the flattening step is carried out without exposing the silicon surface to an air.

45. A method as claimed in claim 28, wherein the step of forming the oxide film is performed by using gas plasma generated in a mixed gas

of a rare gas selected from at least one of argon, krypton and xenon and an oxygen gas by microwave excitation.

46. A method as claimed in claim 33, wherein the step of carrying out radical oxidation is performed by using gas plasma generated in a mixed gas of a rare gas selected from at least one of argon, krypton and xenon and an oxygen gas by microwave excitation.

47. A method as claimed in claim 27, wherein the flattening step includes oxidizing the silicon surface by using gas plasma generated in a mixed gas of a rare gas selected from at least one of argon, krypton and xenon and an oxygen gas by microwave excitation.

48. A method as claimed in claim 27, wherein the prescribed arithmetical mean deviation of surface is not greater than 0.09nm.

49. A method as claimed in claim 29, further comprising the step of forming an insulation film on the silicon surface;

the insulation film forming step including a selected one of the steps of:

carrying out an oxidation process of the silicon surface in an atmosphere which includes radical oxygen;

processing the silicon surface in an atmosphere which includes radical nitrogen or radical NH; and

processing the silicon surface in the atmosphere which includes radical oxygen and at least one of radical nitrogen and radical NH.

50. A method as claimed in claim 49, wherein the insulation film forming step comprises the steps of:

preparing a mixed gas of a rare gas selected from at least one of argon, krypton and xenon and an insulation film forming gas selected from at least one of ammonia, oxygen, nitrogen, NO and N_2O; and generating plasma in the mixed gas by microwave excitation to form the insulation film.

51. A method as claimed in claim 27, wherein the flattening step comprises:

a first step of forming, on the silicon surface, an oxide film by carrying out oxidation process by the use of H_2O vapor;

a second step of removing a portion of the entire thickness of the oxide film to leave a thickness between 10 angstroms and 1000 angstroms of the oxide film on the silicon surface; the first and the second steps being performed at least once, respectively; and

a third step of completely removing the oxide film by an aqueous solution including HF.

52. A method as claimed in claim 27, further comprising the step of cleaning the silicon surface.

53. A method as claimed in claim 52, wherein the cleaning step comprises the step of:

cleaning the silicon surface in accordance with the RCA cleaning procedure wherein an OH concentration is reduced.

54. A method as claimed in claim 52, wherein the cleaning step comprises the step of:

cleaning the silicon surface with cleaning liquid having a pH value of not more than 7.

55. A method as claimed in claim 52, wherein the cleaning step comprises:

a first step of rinsing the silicon surface by using pure water including ozone;

a second step of cleaning the silicon surface by the use of a cleaning solution which includes HF, H_2O with dissolved oxygen reduced, and surface-active agent, providing a vibration of a frequency not lower than 500 kHz;

a third step of rinsing the silicon surface by the use of H_2O including ozone;

a fourth step of cleaning the silicon surface by the use of a cleaning solution including HF and H_2O with dissolved oxygen reduced so as to remove an oxide film; and

a fifth step of rinsing the silicon surface by the use of hydrogen-added H_2O.

56. A method as claimed in claim 55, wherein hydrogen is added to the cleaning solution of at least one of the second step and the fourth step.

57. A method as claimed in claim 52, wherein the cleaning step includes processing the silicon surface by the use of a cleaning solution containing HF and H_2O with dissolved oxygen of less than 100 ppb.

58. A method as claimed in claim 52, wherein the cleaning step comprises the steps of:

preparing a cleaning solution which includes HF, H_2O with dissolved oxygen of less than 100ppb and hydrogen of 0.1ppm to 1.6ppm; and

providing the cleaning solution with a vibration of a frequency not lower than 500kHz.

59. A method as claimed in claim 52, wherein the cleaning step is carried out without exposing the silicon surface to an air.

60. A method as claimed in claim 52, wherein the cleaning step is carried out by contacting the silicon surface with cleaning liquid with applying ultrasonic vibration to the cleaning liquid while generation of OH in the cleaning liquid is suppressed.

61. A method of manufacturing a semiconductor device, comprising the steps of:

preparing a silicon semiconductor surface which has a predetermined crystal plane orientation; and

rinsing the silicon surface by the use of H_2O added with hydrogen or deuterium and by applying high frequency vibration to said H_2O to terminate silicon at the silicon surface by hydrogen or deuterium, respectively.

62. A method as claimed in claim 61, wherein said high frequency is not less than 500kHz and the concentration of said hydrogen or deuterium in said H_2O is 0.1ppm to 1.6ppm.

63. A method as claimed in claim 27, wherein the flattening step comprises the step of:

rinsing the silicon surface by the use of H_2O added with hydrogen or deuterium and by applying high frequency vibration to said H_2O to terminate silicon at the silicon surface by hydrogen or deuterium, respectively.

64. A method as claimed in claim 63, wherein the rinsing step comprises one of the steps of:

dipping or immersing the silicon surface into the H_2O added with hydrogen or deuterium; and

spraying, onto the silicon surface, H_2O added with hydrogen or deuterium.

65. A method as claimed in claim 63, wherein said high frequency is not less than 500kHz and the concentration of said hydrogen or deuterium in said H_2O is 0.1ppm to 1.6ppm.

66. A method as claimed in claim 27, wherein the flattening step comprises:

a first step of cleaning the silicon surface by the use of H_2O including ozone;

a second step of carrying out cleaning by a cleaning solution including HF, H_2O and a surface-active agent, providing vibrations of a frequency not lower than 500kHz;

a third step of carrying out cleaning by H_2O including ozone;

a fourth step of carrying out cleaning to remove an oxide film by the use of a cleaning solution including HF and H_2O; and

a fifth step of carrying out cleaning by using hydrogen or deuterium-added H_2O, providing vibrations of a frequency not lower than 500 kHz, so as to terminate the silicon surface by hydrogen or deuterium, respectively.

67. A method as claimed in claim 66, wherein oxygen is removed from the H_2O in the second and the fourth steps and hydrogen is added thereto.

68. A method as claimed in claim 61, wherein the rinsing step is carried out with the silicon surface being kept isolated from the air.

69. A method as claimed in claim 66, wherein the first to fifth steps are carried out with the silicon surface being kept not exposed to the air.

70. A method as claimed in claim 61, wherein the rinsing step is carried out in an atmosphere of nitrogen, hydrogen, deuterium or mixture of hydrogen and deuterium.

71. A method as claimed in claim 61, wherein the silicon surface has a substantial (110) crystal plane orientation._

72. A method of manufacturing a semiconductor device, comprising the steps of:

preparing a silicon semiconductor surface which has a predetermined crystal plane orientation; and

cleaning the silicon surface,

wherein the cleaning step comprises:

a first step of rinsing the silicon surface by using pure water including ozone;

a second step of cleaning the silicon surface by the use of a cleaning solution which includes HF, H_2O with dissolved oxygen reduced, and surface-active agent, providing a vibration of a frequency not lower than 500 kHz;

a third step of rinsing the silicon surface by the use of H_2O including ozone;

a fourth step of cleaning the silicon surface by the use of a cleaning solution including HF and H_2O with dissolved oxygen reduced so as to remove an oxide film; and

a fifth step of rinsing the silicon surface by the use of hydrogen or heavy hydrogen-added H_2O.

73. A method of manufacturing a semiconductor device, comprising the steps of:

preparing a silicon semiconductor surface which has a predetermined crystal plane orientation; and

cleaning the silicon surface,

wherein the cleaning step comprises:

processing the silicon surface by the use of a cleaning solution containing HF and H_2O with dissolved oxygen of less than 100 ppb.

74. A method as claimed in claim 73, wherein the cleaning step comprises the steps of:

preparing a cleaning solution which includes HF, H_2O with dissolved oxygen of less than 100ppb and hydrogen of 0.1ppm to 1.6ppm; and

providing the cleaning solution with a vibration of a frequency not lower than 500kHz.

75. A method as claimed in claim 73, wherein the cleaning step is carried out without exposing the silicon surface to an air.

76. A method as claimed in claim 72, wherein the fifth step is carried out with vibrations of a frequency not lower than 500 kHz, so as to terminate the silicon surface by hydrogen or heavy hydrogen, respectively.